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The 1991–1992 NSF Young Scholars Program at the University of Hawai'i: Science and Engineering Studies of the Ala Wai Canal, an Urban Estuary in Honolulu[1]

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ABSTRACT: In 1991 and 1992 the School of Ocean and Earth Science and Technology of the University of Hawai'i at Mānoa offered a summer science and engineering enrichment program to a total of 75 Hawai'i students entering 10th through 12th grades. The program was funded by the National Science Foundation's Young Scholars Program. Students participating in the program studied chemical, biological, physical, and geological aspects of the Ala Wai Canal, a small artificial estuary in Waikīkī, Hawai'i. The program provided the students with an opportunity to participate in original research through multidisciplinary (botany, civil engineering, computer sciences, geology and geophysics, microbiology, oceanography) scientific and engineering projects. Results of the students' work have contributed to an increased understanding of the physical condition of the canal, the level of pollution involved, and the potential for cleanup.

THE ALA WAI CANAL, located immediately north of the resort area of Waikīkī in Honolulu, Hawai'i (Figure 1), was designed as part of a reclamation project for the Waikīkī area of Honolulu in 1919. The canal is 3100 m long and varies in width from ca. 51 to 83 m (Figure 2). A 55° bend in the canal is located about one-third the distance from the mouth. The intent of the design was to control flooding of the region, improve sanitation, and permit reclamation of the marshlands and swamps that constituted the distributary regions of streams that drained three major watershed areas, Mānoa, Pālolo, and Makiki, on the south shore of O'ahu (Sunn et al. 1977). Dredging to start construction began in 1921 and was essentially completed in 1927 with additional work continuing until 1929 (Cox and Miller 1976, Sunn et al. 1977). Subsequent modifications to the canal include shoring up of the edges of the canal with retaining walls and with several structures that direct discharge from streams and runoff.

The Ala Wai Canal receives runoff from two principal watersheds and three minor areas (Figure 1). The combined Mānoa-Pālolo watersheds provide 58% of the total input to the canal, and the Makiki watershed combined with runoff from Waikīkī, Kapahulu, and Ala Moana areas contribute the remainder (Sunn et al. 1977). The total land area involved is 41.6 km^2. Peak runoff was calculated by Sunn et al. (1977) as follows: Mānoa-Pālolo, 382 m^3/sec (13,500 cfs [cubic feet/second]); Makiki, 161 m^3/sec (5700 cfs); the combined Kapahulu and Waikīkī areas, 59 m^3/sec (2100 cfs); and the Ala Moana area, 59 m^3/sec (2100 cfs), for a total of 661 m^3/sec (23,400 cfs).

The depth of the canal varies from ca. 5 m to less than a few centimeters (Figure 3). The shallowest portions of the canal are where stream discharge has been directed into the canal through drainage canals (Figure 4). Occasionally the deltaic deposits from the drainage canals are subaerial. Sedimentation

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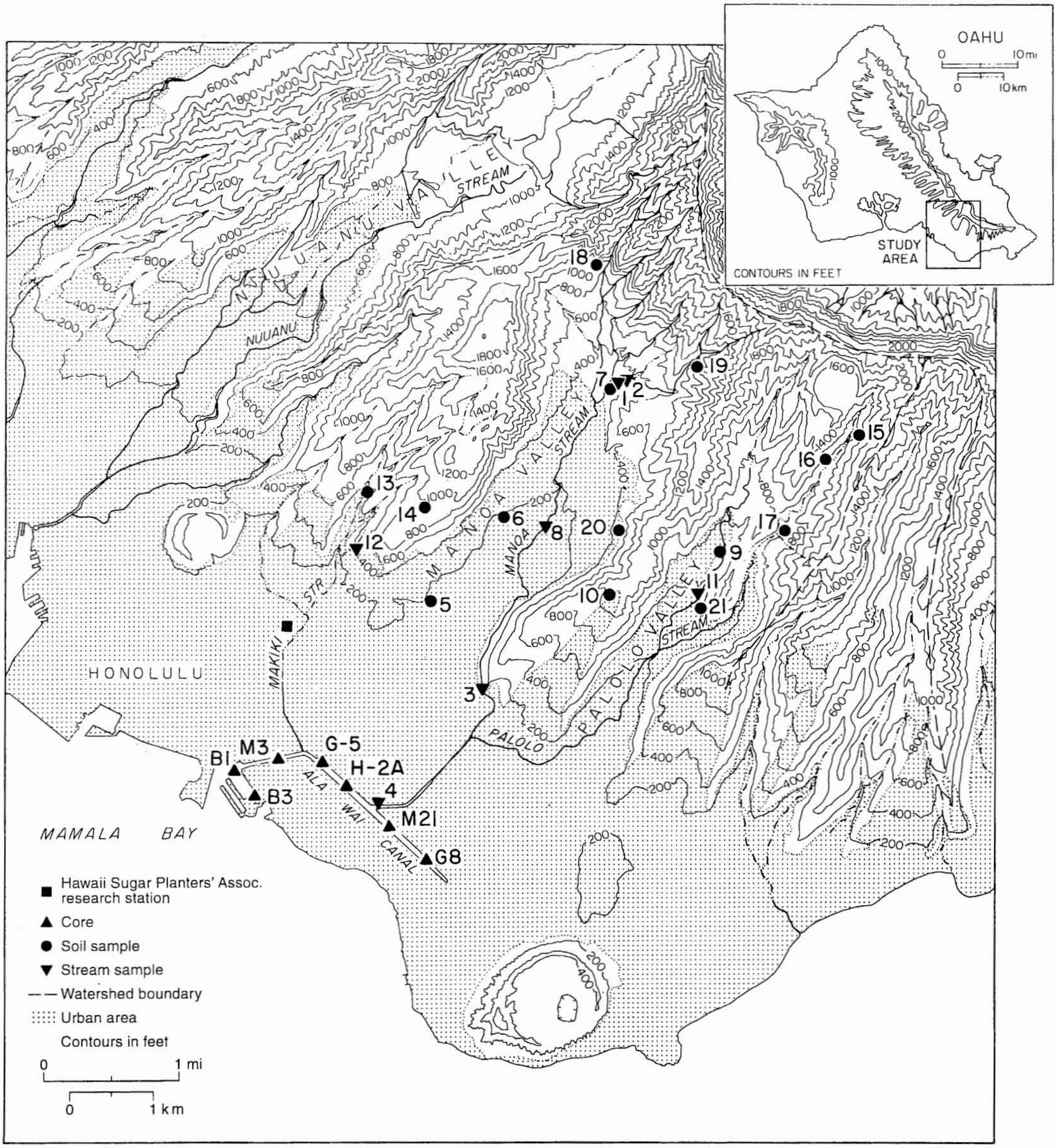

FIGURE 1. Topographic map of the Honolulu area showing the relationship of the Ala Wai Canal to the Honolulu and Waikīkī areas of the Hawaiian island of O'ahu (inset). Locations designated by solid symbols refer to sample localities from which water or soil materials were collected for analysis. Contour interval for this map is 200 ft.

occurs at a rate of ca. 7–8 × 10^3 m^3/yr (Laws et al. 1993). The three streams that originally drained into the region are now confined to two main drainage canals, Mānoa-Pālolo drainage canal and the Makiki drainage canal. Several large drains also feed the canal, particularly at the east end. Dredging of the canal in 1966 and 1978–1979 removed some of the accumulated sediments. The 1978–1979 dredging deepened the canal to a uniform depth of 3 m from McCully Street to the mouth of the Mānoa-Pālolo drainage canal.

Cultural hypereutrophication of the canal,

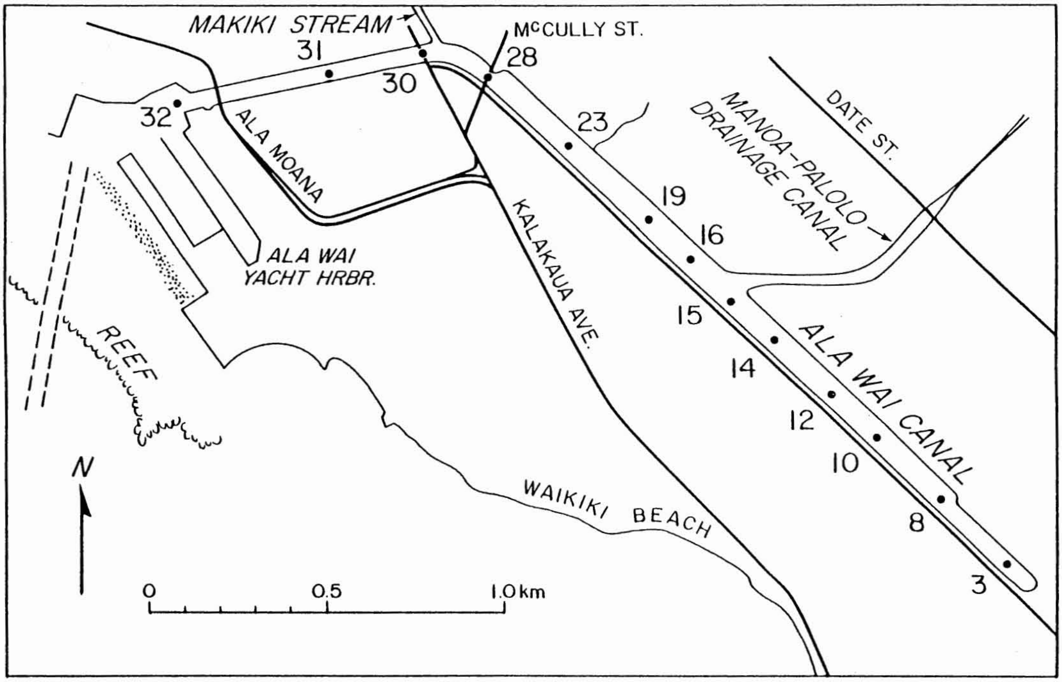

FIGURE 2. Schematic map of the Ala Wai Canal showing physical relationships of the canal to the Waikīkī shoreline and to major streams and drainage canals that feed the canal. Major roads are indicated by solid lines annotated with street names. (From Laws et al. [1993].)

consequent poorly oxygenated bottom waters, bacterial contamination, and generally low esthetic conditions have prompted the state of Hawai'i to address concerns regarding cleanup efforts over the last several years. The small size of the canal, its simple geometry, and the restriction of input to a few point sources make the canal an ideal place for observations and theoretical studies of both the current conditions and the prospect for cleanup of the canal. In 1991 and 1992 the School of Ocean and Earth Science and Technology of the University of Hawai'i at Mānoa offered a summer science and engineering enrichment program, which I directed, to a total of 75 students from 32 high schools in the state of Hawai'i. The students were entering 10th through 12th grades. The program was funded by the National Science Foundation's (NSF) Young Scholars Program. For 6-week periods during the summers the students lived on the University of Hawai'i at Mānoa campus and were supervised by faculty and staff members from the College of Education, the College of Engineering, the College of Natural Sciences, the School of Ocean and Earth Science and Technology of the University of Hawai'i, and Operation Manong, an educational outreach program at the University of Hawai'i. The students engaged in original directed research projects and took part in enrichment classes and career-guidance activities.

Structure of the Program

The NSF Young Scholars Program has two principal goals: (1) to provide qualified high-school students with an opportunity for involvement in applied scientific research under the supervision of university research scientists and technicians; and (2) to increase the potential for students to choose science and engineering professions. To this end the science and engineering studies of the Ala Wai Canal program was developed to offer

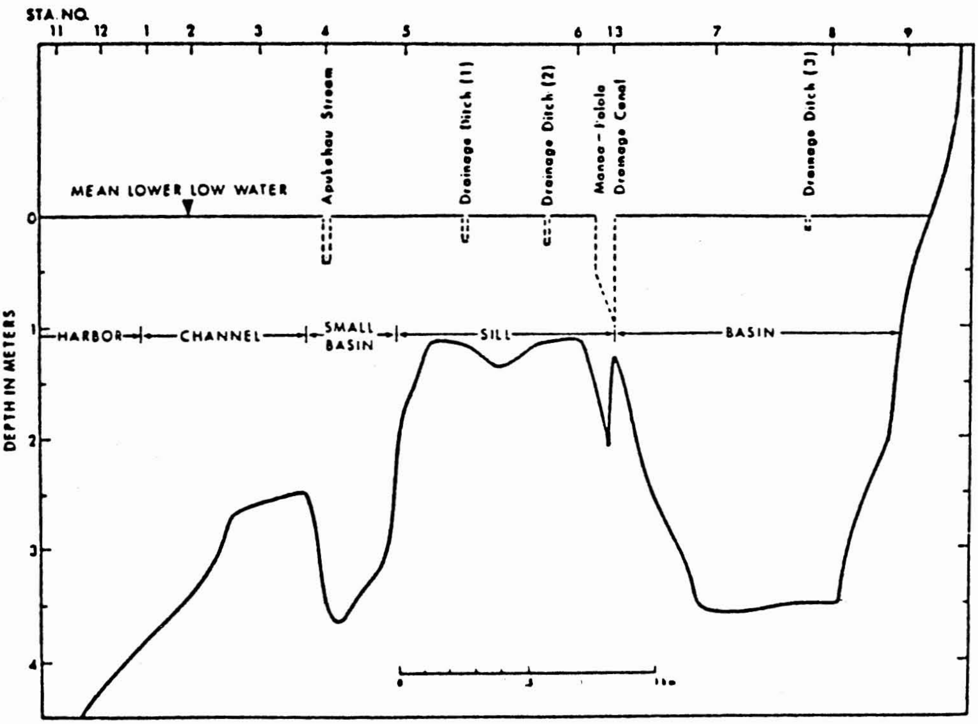

FIGURE 3. Longitudinal cross section of the Ala Wai Canal at mean low water showing the stream and drainage ditch entrances to the canal and the variations in depth along the length of the canal. The depths of the canal shown were determined in 1965. (From Gonzalez [1971].)

the students a chance to gain first-hand experience in state-of-the-art research laboratories. The students were given a chance to address environmental problems using a multidisciplinary approach (botany, civil engineering, computer sciences, geology and geophysics, microbiology, oceanography) to solve an environmentally relevant problem.

RESEARCH PROJECTS. The students engaged in a variety of original research projects focusing on various aspects of the evaluation of current conditions of and on the potential for cleanup of the canal. Mentors for the students were drawn from university research specialists from several departments and research institutes at the University of Hawai'i at Mānoa. The results of the research projects are summarized in the following section.

COURSES. Formal course work offered to the students included the following:

(a) Statistics and Data Analysis: Dr. Eric De Carlo presented a short course in the scientific analysis of data emphasizing the basic skills required of the successful research scientist and stressed the ethical presentation of data. The principles presented in this course were reinforced by most of the research team leaders, although some did not have use for statistical evaluation of the data collected. The data analysis aspects were augmented by the information and computer sciences course.

(b) Pollution Studies: Dr. Edward Laws presented a course in aquatic pollution that ran for the full length of the program. The class traced the human impact on marine and freshwater biological systems. This course was an abbreviated version of a class taught to undergraduate students during Summer Session Oceanography 320 (Aquatic Pollution) at the University of Hawai'i.

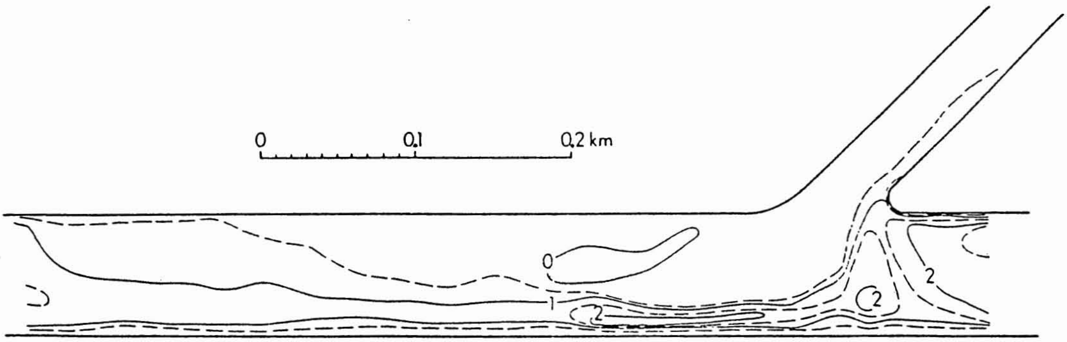

FIGURE 4. A detailed bathymetry map of the region near the Mānoa-Pālolo Stream drainage ditch from data of May 1965 shows the distribution of sediment deposited by stream discharge at this site. Contour interval is 0.5 m (dashed lines) with 1.0-m intervals highlighted (solid lines). Depths are given in relation to mean lower low water. (From Gonzalez [1971].)

(c) Engineering Studies: Dr. Clark Liu of the Civil Engineering Department and Dr. Hans Krock of the Department of Ocean Engineering presented four lectures guiding the students through discussions of possible engineering alternatives for improving the water quality conditions of the Ala Wai Canal.

(d) Information and Computer Sciences: Three staff members of the University of Hawai'i Computer Center under direction of Ms. Jody Chiu of the University of Hawai'i Computer Center presented a computer course in the application of word processing, spreadsheets, and graphics programs software using Macintosh computers. The laboratory sessions were held in the CLIC Laboratory in Sinclair Library at the University of Hawai'i at Mānoa. The students were split into two groups based on familiarity with computers, and each group was instructed sequentially in the use of the software applications outlined. In addition, Mr. Bruce Campbell of the Department of Education instructed the students in the use of the Hypercard application as a means of preparing a final report for presentation at the end of the program.

CAREER EDUCATION. The students explored career choices through discussions of the types of preparation necessary for careers related to science and engineering as part of the History of Science seminar series and as part of the field trips. This provided students with the opportunity to meet professors from other fields.

The students also made visits to on- and off-campus research laboratories and institutions. These visits provided the opportunity to examine a variety of science and engineering careers. The sites visited included the Planetary Geoscience Division of the University of Hawai'i, the Sand Island Sewage Treatment Plant and Chemical Laboratories (a primary sewage treatment plant), the Wahiawa Sewage Treatment Center (a secondary treatment plant), the University of Hawai'i Hazardous/Radioactive Waste Treatment Facility, and the Coconut Island research facility of the Hawai'i Institute for Marine Biology. The students were given an exposure to careers in anatomy, aquaculture, botany, civil engineering, mathematics, marine biology, marine geology, physics, planetary geology, politics, teaching, and water quality management.

NETWORKING AND COOPERATION. Weekly meetings of the mentors were held to review progress and to address problems as they arose. The mentors also shared results to date and set up cooperative ventures between research groups. Halfway through the program the students gave formal presentations of their results and discussed the probable outcome of their research.

FINAL PRESENTATIONS. Students worked together to construct Hypercard stacks suitable for display at the final presentation on the last day of the program. The students also worked in groups to assemble posters for display at the final presentation. The president of the University of Hawai'i, several vice presidents, and the parents of the students attended the presentations that were held the last day of the program.

FOLLOW-UP ACTIVITIES. Students were required to present the results of their research projects to their science classes in the high schools during the following semester. The students also were required to present the results of their research either as papers in the Annual Student Symposium on Marine Affairs or as entries in the 1993 Hawai'i Science and Engineering Fair. The students' mentors and science teachers from the students' schools assisted the students in preparing these presentations.

Results of Research Projects

The first year of the program concentrated on the current conditions of the Ala Wai Canal. An evaluation of the water quality and the potential for cleanup, as well as the possible consequences of cleanup were addressed. The following extracts from the final reports of the students and mentors briefly describe the nature of the students' efforts.

First Year of the Program, 1991

BACTERIOLOGY STUDIES (Mentor, Mr. Wes Riley). One of the students, Janis Taniyama, performed a bacteriophage experiment and was successful in detecting the presence of bacteria-borne viruses in the Ala Wai. Previously, no published results of similar bacteriophage experiments had been available. The conclusion from this study is that the spread of viruses through the host-virus interaction in the Ala Wai presents a hazard to the health and safety of those who come into contact with the water. Laura Anderson, Archie Chen, and Eddie Lactaoen, working in microbiology, determined that the entrance to the yacht harbor shows the highest level of contamination and reflects a human component. The principal source of fecal coliform and fecal streptococcus in the remainder of the Ala Wai Canal is from nonhuman biological sources, except that near the mouth of the Mānoa-Pālolo Stream. In general, the studies show that by continental U.S. standards the canal is unfit for use (Hawai'i has a more lenient standard, because of the higher sustained temperature in the waters). Furthermore, the students determined that the bacteria present in the Ala Wai Canal are highly resistant to antibiotics. A study of the tissue of living fish from the Ala Wai by Kent Yamamoto showed that the fish are unfit for consumption.

BOTANY STUDIES (Mentors, Ms. Shannon Fairres and Dr. Celia Smith). Elizen Cadavolla, Lea Cuevo, Kelly Kaumeheiwa, Jubilee Konohia, Laressa Dimalanta, and Alma Trinidad investigated the effects of current water conditions on several types of seaweeds to compare the Ala Wai conditions with those required for healthy growth of these plants. The students concluded that limited tidal flushing and consequent poor circulation restricts conditions adequate for the growth of the algae studied to only near the mouth of the Ala Wai Canal.

NUTRIENT STUDIES (Mentor, Dr. Marlin Atkinson). Merna Hsu, Ann Moriyama, Joanna Oda, Sharon Oshiro, and Matthew Skeele examined content and distribution of nutrients (nitrates, phosphates, and ammonia) in the canal. These nutrients are responsible for high levels of phytoplankton in the waters. The nutrients are introduced into the canal primarily by runoff.

DISSOLVED OXYGEN STUDIES (Mentor, Dr. Edward Laws). Dominador Doliente, Shigehiro Minami, and Kay Kim measured amounts of dissolved oxygen in the water to trace the complex interaction between photosynthetic activity of phytoplankton in the water and the tendency of the water to lose oxygen by respiration and diffusion during the night when the phytoplankton do no photosynthesis. They also noted the drop-off in productivity (the amount of phytoplankton the water produces per unit volume) with depth below a few feet because of the high surface productivity and the consequent reduction of light available for photosynthesis below that depth. The bottom waters reach low oxygen conditions, thus possibly contributing to the reported foul smells attributed to the Ala Wai Canal waters. In a related study, Jamelle Hirayama, Mai-Li Hokama, and Christina Morales determined the variations in rate of photosynthesis in the canal. Their data show that the phytoplankton are at the theoretical maximum with respect to nutrients present. The students found that the greatest rate of photosynthesis was at the Ala Wai Golf Course sampling station. There the productivity is comparable with commercial efforts at algal mass production. According to the results of the studies, the Ala Wai Canal is the most heavily fertilized estuary in the world. The detailed results of these projects have been described by Laws et al. (1993).

CIVIL ENGINEERING STUDIES (Mentors, Drs. Edward Laws and Clark Liu). De Wang Li and Dana Yamate worked on a hydrodynamic model of fluid flow in the Ala Wai Canal. The results of this type of modeling indicate that very little water exchange occurs east of the Mānoa-Pālolo Stream mouth (toward the Diamond Head end). There is intermittent circulation of colder bottom water over the delta located at the mouth of the Mānoa-Pālolo Stream and into the Diamond Head end of the canal. However, this circulation does not occur during normal daily tidal fluctuations. Tidal fluctuations involve the cooler, denser salt water on the bottom of the canal west of the Mānoa-Pālolo Stream delta. The upper few feet of freshwater from the streams and from runoff are involved only to a minor extent in vertical circulation of water in the canal.

PALEONTOLOGY STUDIES (Mentor, Dr. Johanna Resig). Kristine Ming and Scott Miyake examined populations of foraminifera in five sediment cores from the canal and report their results in Resig et al. (1995). The students identified a maximum of 26 species near the mouth of the canal and noted that the diversity of organisms falls off with distance from the mouth. In the Diamond Head end of the canal there are five dominant species that adapt well to low oxygen conditions. Evidence of abnormalities in the tests of the foraminifera and infilling of some tests with pyrite are consistent with anoxic and/or toxic conditions in the sediments at the Diamond Head end of the canal. The students compared their observations with studies of several types of polluted environments and conclude that the foraminiferal data suggest some effects of pollution, but not to the extent of inhibiting productivity in the canal (Resig et al. 1995).

SEDIMENTOLOGY AND GEOCHEMISTRY STUDIES (Mentors, Drs. Eric De Carlo, Craig Glenn, and Gary McMurtry). Dale Hope, Yoo Sin Kang, Jennifer Kim, and Malia Moniz investigated the history of the sediments deposited in the Ala Wai Canal and determined a sedimentation rate of 2.5 cm/yr. The organic carbon content, which reflects the input of nutrients to the canal, shows an inverse relationship with depth in the core. Brook Maples, Douglas McCrath, and Patrick Unemori investigated the rate of sedimentation of these cores by analyzing them for the radiogenic isotopes ^{210}Pb and ^{234}Th and determined a sedimentation rate of 2.56 cm/yr, consistent with the estimate from the sedimentation studies. In addition, they studied the distribution of ^{137}Cs generated during the atomic bomb testing in the Pacific Basin over the last 50 yr and were able to correlate the decrease in ^{137}Cs with the nuclear test ban treaty. Karen Corpuz, Alison Furuya, Anna Guillermo, and Margaret Li investigated the heavy metal content of the sediments and found correlations with environmental legislation restricting the lead content of gasoline. The Pb content of the sediments was seen to increase dramatically after the advent of automobile use on the island. The Pb content of the sediments drops off again after the use of unleaded gasoline was required. The levels of Ba, Cr, Cu, Fe, Mn, Pb, and Zn are all high in the canal sediments. Results of the students' studies show that these sediments are not currently a major contributor to the pollution of the Ala Wai waters because the sediments are effectively isolated from interaction with the water; thus the heavy metals remain in the sediments (Glenn et al. 1995).

Second Year of the Program, 1992

Studies engaged in during the second year of the program were to some extent extensions of the first year's students' results. Data from the first year were incorporated into the results of some of the second-year projects; thus a considerably greater level of sophistication in the research projects was possible. During the second year it was possible to employ detailed hydrology modeling and civil engineering studies to determine possible alternatives for cleanup of the canal. The papers resulting from the students' work over the 2 years of the program and additional research performed by their mentors provide a synthesis of the conclusions reached during the program.

HEAVY METAL STUDIES (Mentor, Dr. Eric De Carlo). Christy Chung, Wendy Matsuno, Jan Nakamura, and Kai Ki Mow determined the distribution and abundance of Al, Ba, Ca, Cd, Co, Cr, Cu, Ni, Fe, Mg, Mn, P, Pb, Si, Sn, Sr, V, and Zn in 45 samples from 2-cm-thick layers every 4 cm of a 1.7-m sediment core from the canal. The core was recovered from near the bank of the canal. A core studied in the previous year was collected in the center of the canal at about the same position along the length of the canal. The students correlated the results of analysis of samples from these two cores. The data from the 1992 analysis matched that of 1991 except that the more compressed sedimentation pattern reflected the proximity of the 1992 core to the bank. The data show a near perfect correlation of the Pb abundances with the advent of the use of tetraethyl Pb additives in automotive fuels. A strong positive correlation exists between Zn abundance and amount of automotive traffic (Zn is used in the vulcanization of rubber). A strong record of increased boating activity in the outer Ala Wai Yacht Harbor correlates positively with increase in the Cu concentration in more recent sediments (bottom antifoulant paint). An increase in Cd with time probably reflects the use of superphosphate fertilizer. An increase with time in Co and Ni reflects increased use of products containing these metals with the increased urbanization of Honolulu over the past 50 yr. The same trends are observed in both cores, and the temporal correlations are confirmed by radiometric dating performed on samples from both cores that were supervised by Dr. Gary McMurtry.

The work of these students prompted additional research by De Carlo and Spencer (1995), McMurtry et al. (1995*b*), Spencer et al. (1995), and Raine et al. (1995).

BACTERIOLOGY STUDIES (Mentor, Dr. Fred Dobbs). Joy Aguilar, Nancy Liu, and David Wong worked on microbiological studies of the Ala Wai Canal. Each designed a project of his or her choice directly or indirectly related to the summer's overall theme. Joy Aguilar studied effects of ultraviolet radiation on the bacteria in the water of the Ala Wai Canal. She evaluated irradiation as a means of killing water-column bacteria (total, enterococci, and coliform) and found that with few exceptions, the exposure to UV light killed all bacteria in water samples from three locations in the canal. Joy envisions a possible scale-up of this method as a way of "disinfecting" canal waters. Nancy Liu studied the effectiveness of aeration in lowering bacterial populations in samples from the canal. She established three sets of laboratory microcosms having the following treatments: aeration, no aeration, and aeration with addition of nutrients. The last treatment took into consideration the input of nutrients from freshwater inflow into the canal. Nancy enumerated bacterial populations (total and enterococci) over time and simultaneously determined the microcosms' biochemical oxygen demand (BOD). Although her BOD results were confounded by methodological problems, she found that aeration indeed reduced bacterial populations, although not as quickly as hypothesized. Thus, she has shown that a time-tested, low-cost approach for water-quality management might be successfully applied to the canal. David Wong's project, on antibiotic resistance in the Ala Wai Canal, began as an attempt to determine the concentration of antibiotic-resistant bacteria in the canal's waters. Resistance appeared to be extremely widespread, even at high titers of antibiotic.

HYDROLOGY STUDIES (Mentor, Dr. Ali El-Kadi). William Ignacio, Michelle Lai, and Victor Lam used a mathematical model for the analysis of subsurface flow patterns and chemical transport in the Ala Wai Canal area (1) to describe the interaction between the canal and the shallow-water aquifer, and (2) to examine the possibility of the use of groundwater in the cleanup process as a source of water circulation. The data were collected from published and unpublished reports, from a recently developed geographic information system, and through personal communications. The model solves numerically the partial differential equations describing water flow and chemical transport in the subsurface. Based on simulation results, including sensitivity analyses, the study estimated the ranges of groundwater baseflow and the total chemical loading to the canal. The study surveyed chemicals (fertilizers and pesticides) used on a typical golf course and in urban areas. By comparing those data with levels of chemicals existing currently in the canal's water, the students concluded that groundwater is a source of chemical pollution, especially those chemicals used on the golf course. The study concluded also that the use of subsurface water for cleanup efforts is not feasible, because of scarcity of freshwater and/or the high cost involved. The water and chemical budget for the area, which includes subsurface components, should be considered in any engineering solution to the problem. The study included a recommendation for future research on the development of an integrated model for groundwater, surface runoff, and the canal's surface water body.

MINERALOGY STUDIES (Mentor, Dr. Pow-Foong Fan). Roanna Ng and Deanna Remular studied the mineral assemblages of soil and sediment samples from the Ala Wai Canal and its watershed areas. To understand the origin of the mineralogy of the sediments in the Ala Wai Canal, over 25 soil and stream sediment samples were collected from Mānoa and Pālolo Valleys in cooperation with Dr. Gary McMurtry and his 1992 students. X-ray diffraction analysis was used to determined mineralogical composition of the samples.

Four mineral assemblages are recognized. They are as follows: (1) mechanical weathering products plagioclase, olivine, pyroxene, magnetite, ilmenite, and rutile; (2) chemical weathering products gibbsite, halloysite, montmorillonite, geothite, maghemite, and anatase; (3) aeolian products quartz and mica; and (4) Ala Wai Canal assemblage (detrital): plagioclase, maghemite, and hematite, (marine): halite, pyrite, and calcite (Fan et al. 1995).

SEDIMENTOLOGICAL STUDIES (Mentor, Dr. Craig Glenn). Jeremy Chun, Dawn Strom, Myles Yamamoto, and Melissa Yim worked as a team investigating the stratigraphy, sedimentology, and nutrient geochemistry (organic carbon, calcium carbonate, organic phosphorus, inorganic phosphorus, and total sulfur) of Ala Wai Canal sediments. Myles returned during the school year and reanalyzed another core. He presented his results at one of the Hawai‘i State Science competitions and won an award. The data these students compiled were shared with and critical to many of the other students working with the sediments. Glenn's students established that the Ala Wai has likely maintained anoxic conditions in its back basin sector throughout the past 62 yr. Calculation of organic carbon and phosphorus accumulation rates showed the Ala Wai to be accumulating these elements over 1000 times faster than that calculated for typical highly fertile oceanic upwelling zones. This was attributed to the canal's shallow depth, high rates of primary productivity, and high rates of bulk sedimentation. From downcore organic C/P ratios the students found that despite the direct local inputs of terrigenous sources of organic matter, the organic carbon buried in the sediment was likely dominated by marine phytoplankton and zooplankton sources, as well as by probable inputs from benthic sulfide-oxidizing bacteria that help characterize anoxic bottom waters. Carbon/sulfur relationships were found to correspond closely to those in the modern Black Sea where pyrite forms within the sediments as well as directly from the anoxic water column. The C/S ratios were also interpreted to indicate that about one-third of the organic carbon accumulating in the sediments is likely of terrigenous origin. Unusual carbonate-rich layers tentatively were suggested to have formed as inorganic precipitates in association with periodic elevated blooms in phytoplankton productivity associated with nutrient turnover in the basin (Glenn et al. 1995).

ENGINEERING STUDIES (Mentor, Dr. Hans Krock). Jarrett Imamura, Samuel Kim, Iwalani Pagan, and Man Kit Tsoi worked as a team to develop and test a predictive model of water exchange and dynamics of phytoplankton growth in the Ala Wai Canal. Their objective was to evaluate quantitatively the effectiveness of alternative engineering solutions to the current undesirable water quality conditions in the canal. The database for this model was measurements taken by the students on three field trips and measurements taken by Edward Noda and Associates, Inc. (an ocean engineering consulting firm in Honolulu).

OXYGEN CONCENTRATION (Mentor, Dr. Edward Laws). Jessica Hiraoka, Mary Miura, Bradley Punu, and Carrie Yamamura determined the biomass and metabolic activity of the phytoplankton in the Ala Wai Canal to determine oxygen concentrations in the canal. Phytoplankton are the principal sources of oxygen in most aquatic systems. Respiration of the phytoplankton and that of other microorganisms is the primary cause of oxygen loss. Pigment analyses conducted using liquid chromatography revealed that phytoplankton biomass increased from the mouth to the head of the canal. An analysis of carotenoid pigments, certain of which are diagnostic for particular classes of algae, revealed that the phytoplankton population near the head of the canal is dominated by dinoflagellates, and the population near the mouth consists largely of diatoms. Sampling during dry, sunny weather revealed that the production and consumption of oxygen in the canal were in approximate balance over 24 h. After a heavy rain, consumption resulting from respiration greatly exceeded production via photosynthesis because of the greatly reduced water clarity associated with the input of sediments from stream runoff. A freshwater lens on the surface of the canal was apparent to a depth of ca. 1.0 m. Oxygen concentrations in the bottom waters of the canal violate EPA water quality standards near the head of the canal because of the high respiration rates and poor circulation.

RADIOISOTOPIC STUDIES (Mentor, Dr. Gary McMurtry). Melanie Shiraki and Clayton Yeung studied radioisotopic composition of sediments with field and laboratory assistance from Billy Kang and the two students from Dr. Fan's group (Roanna Ng and Deanna Remular). The students (1) determined sedimentation and bulk accumulation rates for selected sediment cores, and (2) determined soil erosion rates and particle residence times within the Honolulu watershed. The students used fallout ^{137}Cs dating methods. They used modern high-purity Ge gamma spectrometry techniques to assess the activities of these radioisotopes in canal sediments, tributary stream sediments, and watershed soils. Three of the longest sediment cores collected from the canal were subsampled at 4-cm intervals (Gonzales-8, Miller-21, and Miller-3). Splits of these subsamples were then prepared for gamma spectrometry with the remaining portions allocated for trace heavy metal analyses (Dr. De Carlo's group), carbonate and organic carbon analyses (Dr. Glenn's group), and X-ray mineralogy studies (Dr. Fan's group). Dry bulk densities were determined for each subsample from measured subsample volumes and sediment weights after drying at 110°C.

Overall mean sedimentation rates determined by the fallout ^{137}Cs for each 4-cm interval ranged from less than 0.1 g/cm^3 per month to more than 1.0 g/cm^3 per month (McMurtry et al. 1995*a*).

To determine soil erosion rates and particle residence times within the Honolulu watershed, the students collected additional samples of tributary stream sediments and soil horizons within the watershed after studying optimum sampling sites using available topographic maps and aerial photographs. Once analyzed, the soil and stream samples were expected to provide the necessary complementary data for fallout ^{137}Cs model calculations involving the canal as sink and the watershed as source (McMurtry et al. 1995*a*).

BOTANY STUDIES (Mentors, Mr. Kevin Beach and Dr. Celia Smith). Robert Harris, Michelle Holsomback, and Melissa Rabago studied and documented the general phytoplankton population in the Ala Wai Canal (Beach et al. 1995). The overall distribution patterns of the phytoplankton from the mouth of the canal to the canal's back end were examined by Robert Harris. The canal's phytoplankton population can be characterized by the dominance of diatoms at the mouth of the canal and dinoflagellates toward the Diamond Head end of the canal. Among the dinoflagellates is the toxic species *Gymnodinium breve*. However, this species is present in quantities too low to present a threat at present. Michelle Holsomback studied the effect of tidal flushing of the canal on the distribution of phytoplankton. *Skeletonema* distribution was found to be influenced greatly by the tidal flux. Studies conducted by Melissa Rabago predicted the changes in the phytoplankton population if the Ala Wai Canal were to be flushed with seawater. She predicted a diatom-dominated phytoplankton flora throughout the canal with seawater flushing. Thus flushing would reduce the risk from the presence of toxic dinoflagellates.

NUTRIENT STUDIES (Mentors, Ms. Teri Rust, Ms. Sue Vink, and Dr. Brian Popp). Rebecca Alipio, Laverne Arcena, Madeline Corpuz, and Christianne Gorospe, with assistance from Kimberly Kothenbeutel, studied the distribution and sources of nutrients (ammonia phosphorus, nitrate, nitrite, and silica) in the Ala Wai Canal. All the students participated in the initial sampling and analysis. Surface water samples and salinity measurements were taken at a number of stations along the length of the canal. The major source of both nitrate and silica was a storm drain located at the Diamond Head end (the head) of the canal. This drain was also a source of phosphate and ammonia, although the input of these two nutrients, relative to the input of nitrate and silica, was much lower. The Makiki and Mānoa-Pālolo Streams are possible sources of ammonia and phosphorus. After initial sampling and analyses, each student chose a particular area in which she was interested and designed a sampling scheme.

Rebecca Alipio determined the overall nutrient distribution in the canal and the effects of rain on this distribution. After a heavy rainfall she collected samples from approximately the same stations as the initial sampling and compared the two measurements (with the exception of nitrite). After the heavy rain, Madeline Corpuz collected some of the suspended sediment delivered to the canal from the streams and storm drains. Madeline filtered the sediment and attempted to determine the potential phosphorus release from the filtrate as it settled out of and/or mixed with more saline water. Laverne Arcena investigated the golf course as a source of nutrients to the canal. From the groundskeepers at the golf course she obtained information about the fertilizers and the fertilizing and irrigation schedule used on the grounds. She collected samples from a number of drains and irrigation ditches that carry groundwater and runoff from the golf course into the canal. Comparison of the nutrient concentrations in these samples with samples taken by Rebecca in the middle of the canal showed similar values. Thus, they concluded that high concentrations of nutrients are not likely to be derived from the golf course. Christianne Gorospe focused on freshwater nutrient sources. She sampled the Mānoa-Pālolo Stream, both before and after the rain, and the storm drain system that leads into the Diamond Head end of the canal. Her results indicated that the drains at the Diamond Head end of the canal are likely the largest source of nutrients, particularly for silica and nitrate, into the canal. The high silica level is indicative of groundwater input. The source of the groundwater was not determined directly; however, it appears to be localized in the area near the outlet of that storm drain system. The source of the extremely high nitrate concentrations in this area was undetermined at the conclusion of the summer research period. The concentrations there are higher than any reported by the USGS for groundwater samples in the Honolulu area (T. Rust and S. Vink, pers. comm., 1992).

Conclusions

The Young Scholars Program has provided 75 high-school students with an opportunity to perform original research in environmental aspects of science and engineering solutions to the problems of pollution of the Ala Wai Canal. The students and their mentors have provided new insight that has altered the view of the Ala Wai Canal. Viruses in bacteria within the canal had never before been discovered, nor had toxic dinoflagellates been found in the Ala Wai Canal. The students' work in both years confirmed that bacteria in the canal are highly resistant to antibiotics. The geochemical content of the sediments had never before been documented with a view toward interpretation of anthropomorphic influences. The paleontology of the sediments had never previously been described. The studies of water quality performed by the students have documented the degree to which human influence on groundwater and runoff has contributed to the pollution of the canal, and have highlighted the intrinsic problems with maintaining standards of water quality that meet governmental requirements. Studies of the potential for cleanup of the canal through hydrological and civil engineering modeling confirm the difficulties with which the state of Hawai'i will have to cope if it intends to address the water quality problems of the Ala Wai Canal. These results have added to the general understanding of the dynamics of this urban estuary system, and through them the students and their mentors have focused attention on an environmental problem of substantial proportions for the City of Honolulu.

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